Space Weather Technical Forecast

Issued on Tuesday, 21 March 2023 at 01:22 Local

This technical forecast provides a four day assessment of space weather events. The probabilities stated below are for reaching or exceeding the given levels. For more information about space weather impacts please see the Met Office Space Weather Scales https://www.metoffice.gov.uk/weather/learn-about/space-weather/uk-scales

Space Weather Forecast Headline: Chance of M-class flares. G1-G2 Minor/Moderate storms likely day 3 (23rd) with coronal hole enhancement and CME arrivals.

Analysis of Space Weather Activity over past 24 hours

Solar Activity: Moderate with one M1.2 flare observed peaking 20/0148 UTC from AR3256 in the southeast disc. This is a longitudinally wide region, with a large leader spot but with a declining trailer spot. The most complex region on the disc is also in the southeast AR3257. This is comprised of two moderately sized negative polarity umbras, and a connected single penumbra region, but also an emergent positive polarity area ahead of the northern spot. The resultant delta-spot configuration suggests increasing instability. There are a total of seven sunspot regions currently on the disc, however the other regions are generally small and simpler, although a number of these are showing signs of growth.

The Earth-facing disc also has a number of filaments across it, and a filament eruption was observed from near AR3258 in the northeast disc around 20/1300 UTC. This resulted in a CME which has been analysed as likely glancing Earth on the 23rd. Further filament eruption events are possible. A second, potentially Earth-directed CME was observed leaving the southwest disc early on the 20th. This was due to a broad reconfiguration of the magnetic structure of the southwest quadrant, clearly visible in SDO aia-193, with the shape and size changes of CH86/-. Analysis has yet to be completed on this CME.

Solar Wind / Geomagnetic Activity: The solar wind speed, as measured at L1, was initially slightly elevated at around 400-450 km/s, but saw an increase to around 480 km/s at 20/1000 UTC, then continued ranging 400-480 km/s thereafter. The density was also largely below average, but showed a slight increase at this time to average levels. This was likely the glancing arrival of the anticipated CME from the 17th, The total IMF strength Bt, remained weak however, around 5-8nT for much of the day. Since 20/1800 UTC this has gradually climbed to be Moderate at 11nT. The north-south component, Bz has been variable, ranging from -8 to +10 nT. The phi angle remained predominately positive (away from the Sun). Geomagnetic activity was Quiet to Active (Kp 0-4), with the strongest activity 20/1500-1800 UTC.

Energetic Particles / Solar Radiation: The high energy proton flux (greater than 10MeV) as measured at GOES-16 is slightly above background, however this is still well below the S1/Minor Storm level and is exhibiting a flat trend. The high energy electron flux (greater than 2MeV) has generally been at background with the associated 24-hour Electron fluence below the Active (1e8 integrated pfu) threshold. At 21/0000 UTC the observed fluence was 7.38e6 integrated pfu.

Four-Day Space Weather Forecast Summary

Solar Activity: Low to Moderate activity is expected, with a chance of isolated M-flares. The main flare risk is currently from the larger regions in the southeast disc, including AR3256 and AR3257.

Solar Wind / Geomagnetic Activity: A CME from the northeast filament eruption on the 20th is expected to give a glancing arrival around 23/1500 UTC. A further CME from the 20th has yet to be analysed. CH85/+ fast winds are expected to give a modest enhancement on day 1 (21st). A

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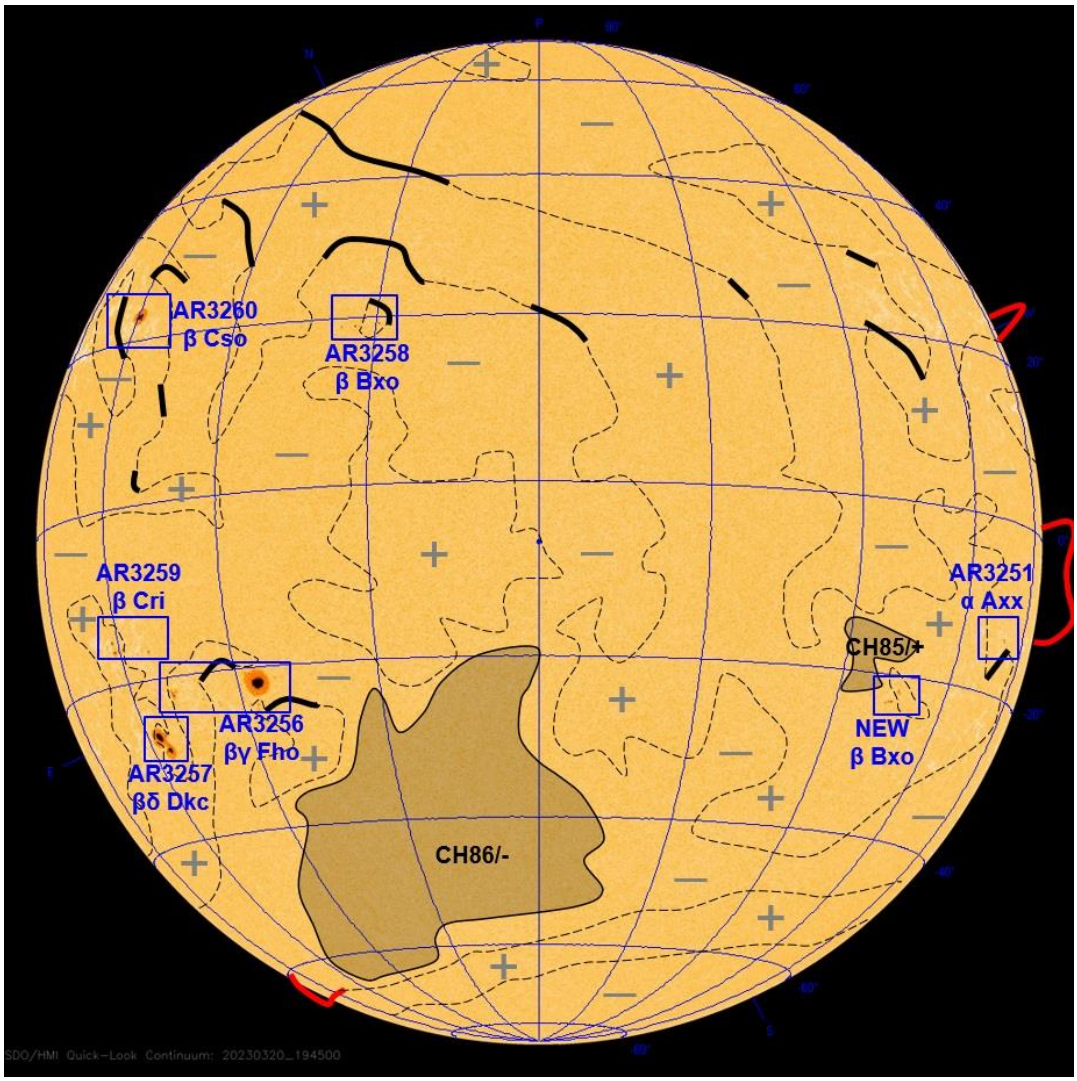
transition into a stronger fast wind region is then expected later day 2 or early day 3 (22nd or 23rd) due to the arrival of the HSS of CH86/- and any associated CIR ahead of it. Quiet geomagnetic activity, with Unsettled intervals, is expected to become Unsettled for a time with a chance of Active intervals day 1 (21st). Activity also increasing day 2 and during day 3, with Active to G1 Minor storm intervals likely due to the coronal hole and CME influence. Unsettled to Active conditions likely follow day 4 (24th) with an ongoing chance of G1 Minor Storm intervals.

Energetic Particles / Solar Radiation: High energy (greater than 10MeV) proton flux is expected to decline to background, albeit erratically, with only a very slight chance of further enhancements given any significant flares occur. The high energy (greater than 2 MeV) electron flux is expected to persist largely at background days 1 to 3 (21st-23rd) before likely rising to Moderate and then High on day 4 (24th) due to the recent enhanced solar wind environment. The associated 24 hour fluence is expected to remain below the Active threshold for much of the period, but with a chance of rising above by the end of day 4.

Figure 1. Solar Analysis Valid 20/2000 UTC.



Key: Filament ___ , Prominence ___ , Magnetic Field Line - - - , Polarity +/-, Coronal Holes: Grey shaded area CHxx +/-, Sunspot groups 25xx - Mt Wilson α-β-βγ-βγδ and Zurich-McIntosh Axx etc.

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Geomagnetic Storms:

There are two CMEs that may give a glancing impact at Earth. The first from was a filament eruption in the northwest disc on the 20th, and is currently forecast to reach Earth's orbit around 23/1500 UTC (day 3). This is likely to only give a minimal impact however, with much of the material passing north and behind Earth. A further CME was also observed on the 20th, leaving the SW disc. Resulting from a broad coronal reconfiguration, this was a much weaker signal in coronagraph imagery, and analysis is still ongoing due to this.

These CME assessments carry low confidence due to the limited available imagery as both SOHO LASCO and STEREO A currently have reduced operational availability.

Earth is also likely to move into the fast wind of CH85/+ on day 1 (21st). This feature is likely the source of the currently enhancement shown at STEREO A, however it is unlikely to give more than a limited enhancement due to its late arrival, and being disfavoured for a strong connection around the March equinox (Russell-McPherron Effect). Solar winds of around 500km/s are likely. CH86/- is then expected to follow this either late day 2 (22nd) or day 3 (23rd). As a persistent and clearly defined feature, a strong enhancement is expected, with winds likely reaching 600-700 km/s, and is expected to be preceded by a relatively strong CIR region. These fast winds are then expected to persist into day 4 (24th)

Quite geomagnetic activity, with Unsettled intervals, is expected to become Unsettled for a time with a chance of Active intervals day 1 (21st). The next notable enhancement is expected late day 2 and during day 3, with Active to G1 Minor storm intervals likely from onset of fast wind from CH86/-, alongside the potential CME arrivals. Unsettled to Active conditions likely follow day 4 (24th) with an ongoing chance of G1 Minor Storm intervals.

Geo-Magnetic Storm Probability (Exceedance)	Level	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC) (%)	Day 2 (00-24 UTC) (%)	Day 3 (00-24 UTC) (%)	Day 4 (00-24 UTC) (%)
Minor or Moderate	G1 to G2	No	10	30	60	40
Strong	G3	No	1	1	5	1
Severe	G4	No	1	1	1	1
Extreme	G5	No	1	1	1	1

Geomagnetic Activity - Earthbound Coronal Mass Ejections

Date/time 21.5R (UTC)	Halo: Full or Partial	Source	Source Location	Estimated Speed	Estimated Arrival Time	Comments
20/1905 UTC	Partial	Filament eruption	NE	815 km/s	23/1500 +/- 9hrs	Low confidence due to limited imagery. Glancing.

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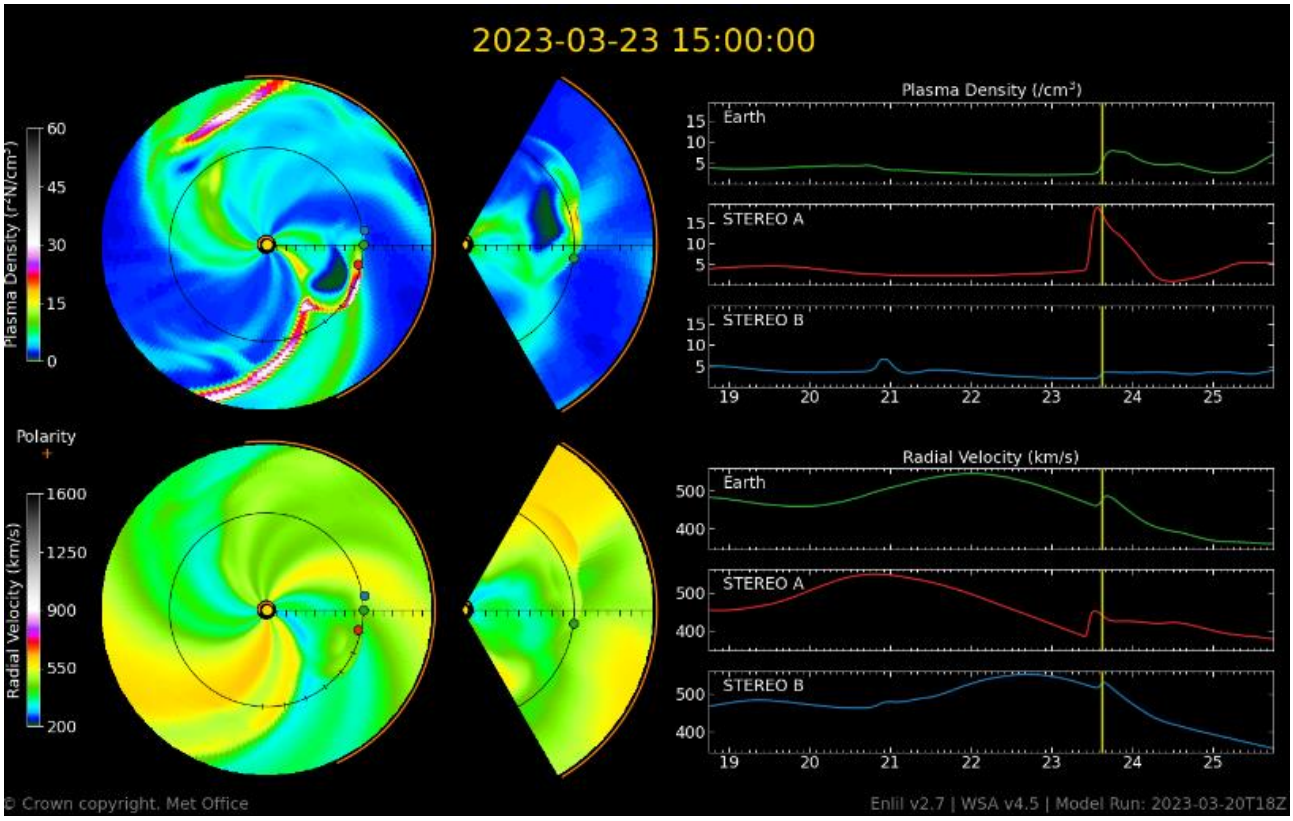
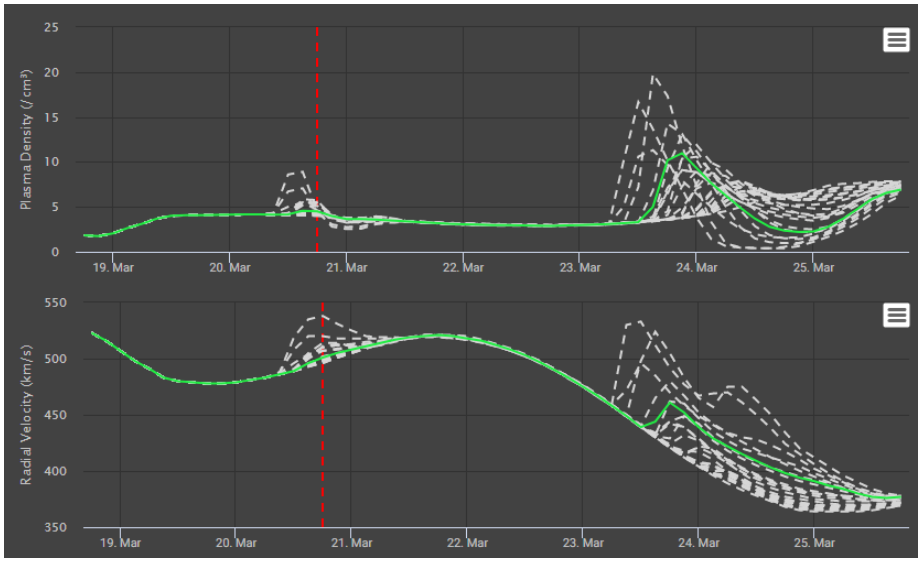
Figure 2: Enlil and ensemble, showing glancing impact of CME on 23rd. However low confidence in Enlil background winds, as well as CME analysis.





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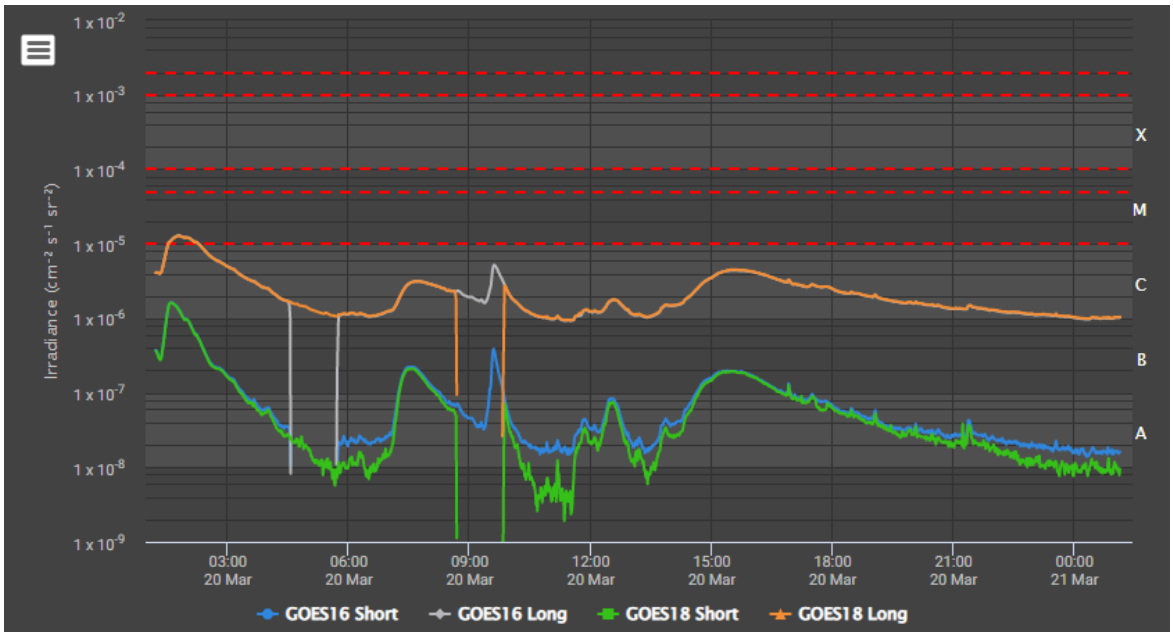
Radio Blackouts - X-Ray Flares:

Low to Moderate activity is expected, with a slight chance of rising to High with the potential for X-class flares

There are seven sunspots on the disc, with activity currently on a general upward trend. The most notable of these spots are in the southeast disc. AR3257 Dkc/Beta-delta is a pair of negative polarity umbra each with symmetric penumbra, but currently connected to create a single compact asymmetric group. Furthermore a small but distinct delta spot has emerged during the last 24 hours, just ahead of the northernmost of these negative spots. This additional complexity is indicative of an increased flare risk from this region. Also in the southeast quadrant AR3256 Fho/Beta-Gamma maintains some complexity, however it has seen its trailer spot weaken, although this has been the source of recent C and M-class flares. The other sunspots on the disc are mostly simple, and currently have a lower chance of flaring, however slow growth is being observed in most of these, with more rapid growth in a region in the southwest.

X Ray Flares	Level	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC)	Day 2 (00-24 UTC)	Day 3 (00-24 UTC)	Day 4 (00-24 UTC)
Probability			(%)	(%)	(%)	(%)
Active	R1-R2 M Class	Yes	40	40	40	40
Very Active	R3 to R5 X Class	No	10	10	10	10

Figure 3: GOES 16/18 X-ray Flux



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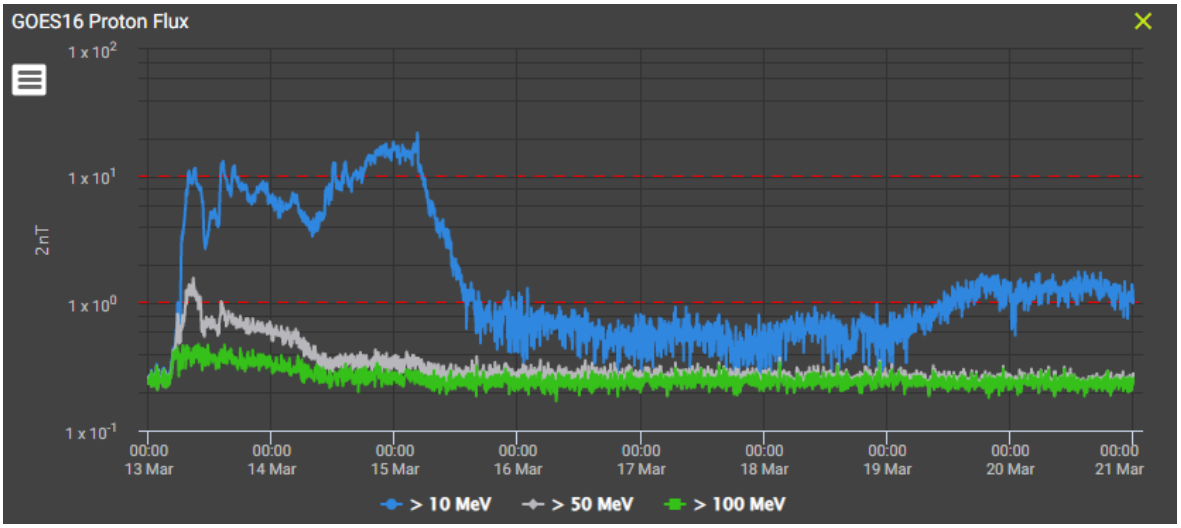
Solar Radiation Storms - (High Energy Protons):

High energy proton flux (greater than 10MeV), as observed by GOES-16 is currently slightly above background as it continues to erratically decline from the S1 Minor Radiation storm event triggered by the large far-sided eruption that occurred on the 13th March. There is a very slight chance of further enhancements, due to the increased flare risk from the sunspot groups in the eastern disc. While not favoured for a strong connection, any significant flares will bring a slight chance of flux levels rising towards, and potentially breaching the S1 Minor Radiation storm level.

Radiation Storms Probability (Exceedance)	Level (cm^{-2} sr^{-1} s^{-1})	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC) (%)	Day 2 (00-24 UTC) (%)	Day 3 (00-24 UTC) (%)	Day 4 (00-24 UTC) (%)
Active	**≥ S1**	No	5	5	5	5
Very Active	**≥ S3 ***	No	1	1	1	1
* S3 ≥ 10 MeV ≥ 1000 pfu and / or ≥ 50 MeV ≥ 10 pfu. (pfu = $cm^{-2}sr^{-1}s^{-1}$)						

Figure 4: GOES 16 >10 MeV, >50 MeV and >100 MeV proton flux since the 13th March



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High Energy Electrons Event (≥ 2MeV):

The high energy (greater than 2MeV) electron flux observed by GOES-16 is expected to be mainly background to Moderate days 1 and 2 (21st and 22nd) with any enhancement from the fast wind arrival of CH85 likely to be limited. The more significant enhancement expected from CH86 on day 3 (23rd), coupled with the potential CME arrivals, will initially being a dropout in values, before likely rising later that day or more likely through day 4 (24th), likely reaching High levels by the end of the period (above 1000 pfu).

The associated 24 hour fluence is expected to be below the Active (1e8 integrate pfu) level through days 1-3 (21st to 23rd) with REFM currently giving good guidance. Fluence levels are then expected to rise through day 4 (24th), with a chance of reaching the Active level by the end of the period.

GEO Electron Environment Probability (Exceedance)	Level (cm^{-2} sr^{-1} day^{-1})	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC) (%)	Day 2 (00-24 UTC) (%)	Day 3 (00-24 UTC) (%)	Day 4 (00-24 UTC) (%)
Active	**≥ 2 MeV ≥ $1x10^8$**	No	1	1	5	40
Very Active	**≥ 2 MeV ≥ $1x10^9$**	No	1	1	1	1

Figure 5: GOES 16 >2MeV Electron Flux (top) and Fluence with REFM (bottom)

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